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DEVELOPMENT OF A 2000 METER AIRCRAFT
EXPENDABLE BATHYTHERMOGRAPH

Contract N00014-82-C-0579

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FINAL REPORT

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SECTION 1

INTRODUCTION

This final report, submitted by Sippican, Inc., of Marion, Massachusetts, summarizes the work accomplished under ONR Contract N00014-82-C-0579 for the development of an air launched 2000-meter expendable bathythermograph (AXBT) design. Probe design modifications were made to achieve a profiling depth capability of 2000 meters, following which a test program was implemented consisting of over-the-side testing, engineering air drop testing and laboratory analyses. It was found that the 2000 Meter AXBT design is a mechanically sound concept; however, a possible offset of temperature with pressure, making temperature exceed the specifications, was observed and requires further analysis. → to p 16

BACKGROUND

Sippican's interest in the 2000 Meter AXBT stems from over 22 years of development and production experience in expendable bathythermograph probes, launchers, and recorders.

In 1962 Sippican recognized the U.S. Navy's need for an expendable, compact, low-cost device for the measurement of ocean temperature as a function of depth, the critical parameter for sonar performance predictions. In response to this need, Sippican undertook an internally funded, \$1.5 million development program which resulted in the design of the innovative Expendable Bathythermograph (XBT) System. As a result, Sippican was awarded in 1969 a three-year production contract for nearly one million XBT's to be supplied to U.S. antisubmarine warfare and research ships. Since 1969 Sippican has produced nearly 3 million XBT's.

Because of Sippican's experience in XBT Buoy and Electronics Design, Sippican was approached by the Office of Naval Research (ONR) in 1975 to examine the possibility of incorporating our XBT into the Navy's Bathythermograph Transmitter Set (the AN/SSQ-36). This system had a temperature profiling depth capability of only 310 meters.

In June 1981 and November 1982, Sippican was awarded contracts by the Naval Avionics Center to manufacture 42,000 AN/SSQ-36 Buoys and 52,000, respectively. These contracts were for buoys which would profile temperature to a depth of 310 meters and these probes were to have the same depth and accuracy as our standard products. After the initial award, the first contract was modified so that 5,720 of the buoys delivered would have a temperature profiling depth capability of 760 meters. Recently the November 1982 contract was modified so that 3,125 buoys would have 760 meter capability.

Since the development of the 760 meter AXBT, it was found that for some applications measurements to 760 meters were still not enough. Therefore, Sippican was contracted to extend the design technology used for the AXBT to develop a probe that could profile to 2000 meters. The approach proposed for this design was intended to use the standard AXBT hardware wherever possible to keep the unit price increase to a minimum without decreasing system reliability.

SECTION 2

DESIGN

The baseline design for the 2000 meter AXBT was developed with the intent of maintaining as much of the standard AXBT design as possible to minimize cost increases. To extend the depth capability to 2000 meters, both mechanical and electrical changes were required in the surface float assembly and probe itself; however, the air package design remained unchanged.

TECHNICAL MODIFICATIONS

Mechanically, the standard AXBT design was modified to accommodate additional wire and to increase the drop rate.

In order to accommodate the extra wire, the probe spool length was increased by 1.25 inches. With the increased probe spool length, the fit between the probe afterbody and sea keeping spool was altered, necessitating the development of a sea keeping spool adapter.

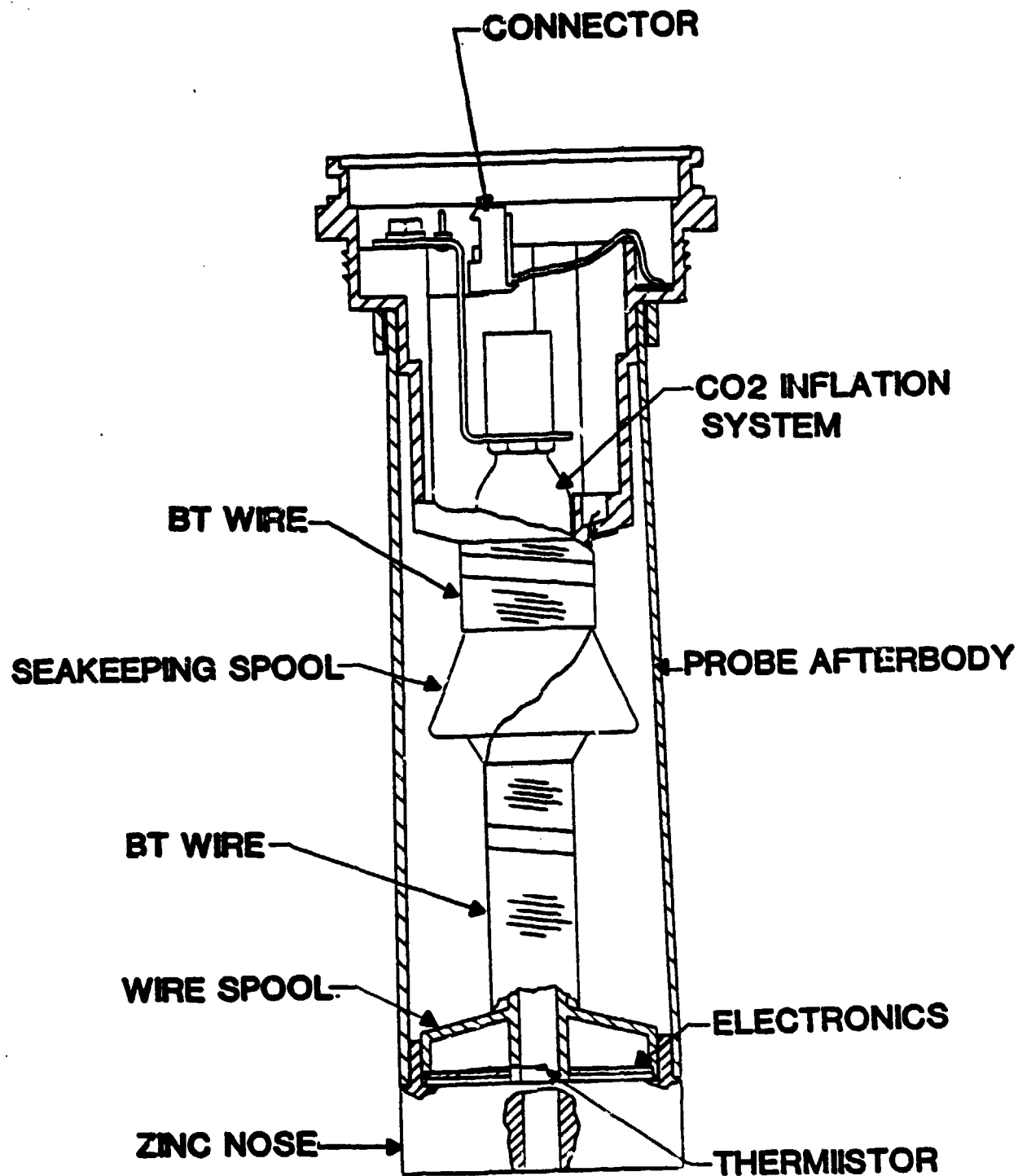
The drop rate criteria were altered with the extended depth capability. The drop rate had to be increased to allow drop completion while the aircraft was still within the RF range limits.

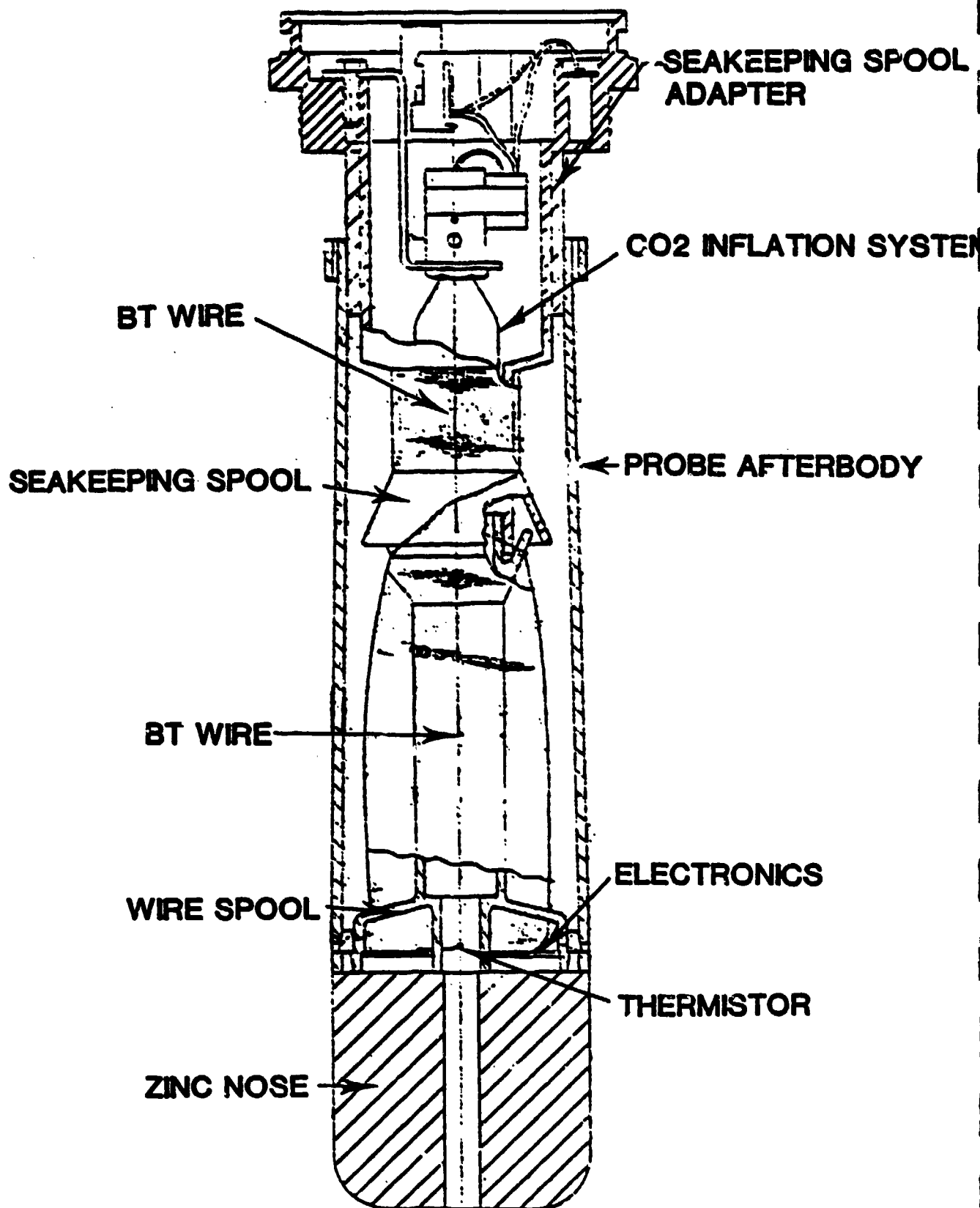
To achieve a more rapid descent rate, both the probe nose weight and drag shape were altered. The probe weight was increased to 1251 grams, and the shape of the probe nose was modified from a flat nose to a slightly rounded one. Figures 1 and 2 show the configurations of the standard and 2000 meter AXBT's, respectively, and depict the mechanical differences resulting from the modifications for the 2000 meter AXBT.

ELECTRICAL MODIFICATIONS

Electrical modifications to both the surface float assembly and the probe were required for the 2000 meter AXBT. A modification to the electronics in the surface float assembly was made to compensate for signal loss. With the addition of wire to the probe, additional resistance was generated resulting in a loss of signal. To compensate for this signal loss, a small 6-volt battery was put in series with the down link power supply to increase the voltage supplied to the probe. The probe electronics were also modified in response to the signal attenuation.

The probe electronics consist of a thermistor, resistor capacitor network, a 4047 CMOS (Complementary Metal-Oxide Semi-conductor) oscillator integrated circuit (IC), a voltage regulator and a transistor line driver. The temperature sensing circuit is configured in an active RC oscillator circuit using a 4047 CMOS IC as the active device. The change implemented in the probe electronics to compensate for the signal loss was a reduction in operating frequency range of the probe (from the standard 1300-2700 Hz to 165-348 Hz). This reduction in frequency accomplished with the addition of a resistor in series with the thermistor provides for one octave of frequency change over the temperature range of -2°C to 35°C (which corresponds approximately to 0.2°C per Hz). Provision is made for individually calibrating each probe by means of a variable trimmer capacitor.

**STANDARD AXBT PROBE****FIGURE 1**

**2000 METER AXBT****FIGURE 2**

The nominal temperature/frequency relationship is defined as:

$$\begin{aligned} T^{\circ}\text{C} = & (-63.9502) + (.830171 \times F) + (-5.1652 \times 10^{-3} \times F^2) \\ & + (2.0501 \times 10^{-5} \times F^3) + (-4.1650 \times 10^{-8} \times F^4) \\ & + (3.5729 \times 10^{-11} \times F^5) \end{aligned}$$

This frequency range insures the proper signal operation level at the surface electronics after wire attenuation.

SECTION 3

TEST PROGRAM

Testing during the development program for the 2000 meter AXBT was done in four phases. The first phase consisted of drop rate measurements; the second, third, and fourth phases were performance tests in an over-the-side deployment, an engineering air drop and a laboratory analysis, respectively.

PHASE 1 - DROP RATE TESTING

The purpose of this phase of testing was to examine the effect of the probe weight and nose shape modifications on the drop rate.

An initial drop rate estimate was made extrapolating data from known probe weights and shapes.

By increasing the weight of the probe to 1251 grams and decreasing drag on the nose, the drop rate was estimated to increase from 1.5 M/sec (standard AXBT drop rate) to approximately 4.5 M/sec $\pm 5\%$.

PHASE 2 - OVER-THE-SIDE DEPLOYMENT TESTING

This test was designed to establish the performance of the 2000 meter AXBT system, beginning with water entry and continuing through drop completion. Testing was done on 11 May 1983, from the R/V Weatherbird in Bermuda. Eight 2000 meter AXBT's and three T-5 XBT's were deployed; data were recorded on a Hewlett-Packard Tape Recorder and a Sippican MK-9 System, respectively.

Much of the data collected had a significant amount of noise interference. All of the AXBT Hewlett-Packard analog tapes had approximately 0.08°C of noise, introduced by the tape recorder itself. Data from one of the three T-5 XBT's and three of the 2000M AXBT's were of good quality (Figures 3 and 4-6 respectively). Table 1 presents a summary of the results. Probe drops 5 and 7 (AXBT S/N 3 and 9) were not retrieved, therefore a failure analysis could not be performed, however, both experienced data cutoff. The other units which failed were retrieved. It was found that the bag did not inflate on Drop 8 (AXBT S/N 8) due to an error in the connection of the battery wire. Finally, the failures observed for drops 9 and 10 (AXBT S/N 13 and 6) were attributed to condensation on the surface printed circuit boards. The condensation was heavy enough to have caused corrosion at several points. The result of this corrosion was the inhibition of the program clock, therefore prohibiting probe release. This failure was successfully duplicated in the laboratory following the cruise. These results indicate that the failures experienced were primarily mechanical in nature, caused by inadequate watertight seals. The AXBT units which did collect data to 2000 meters appeared to be of good quality.

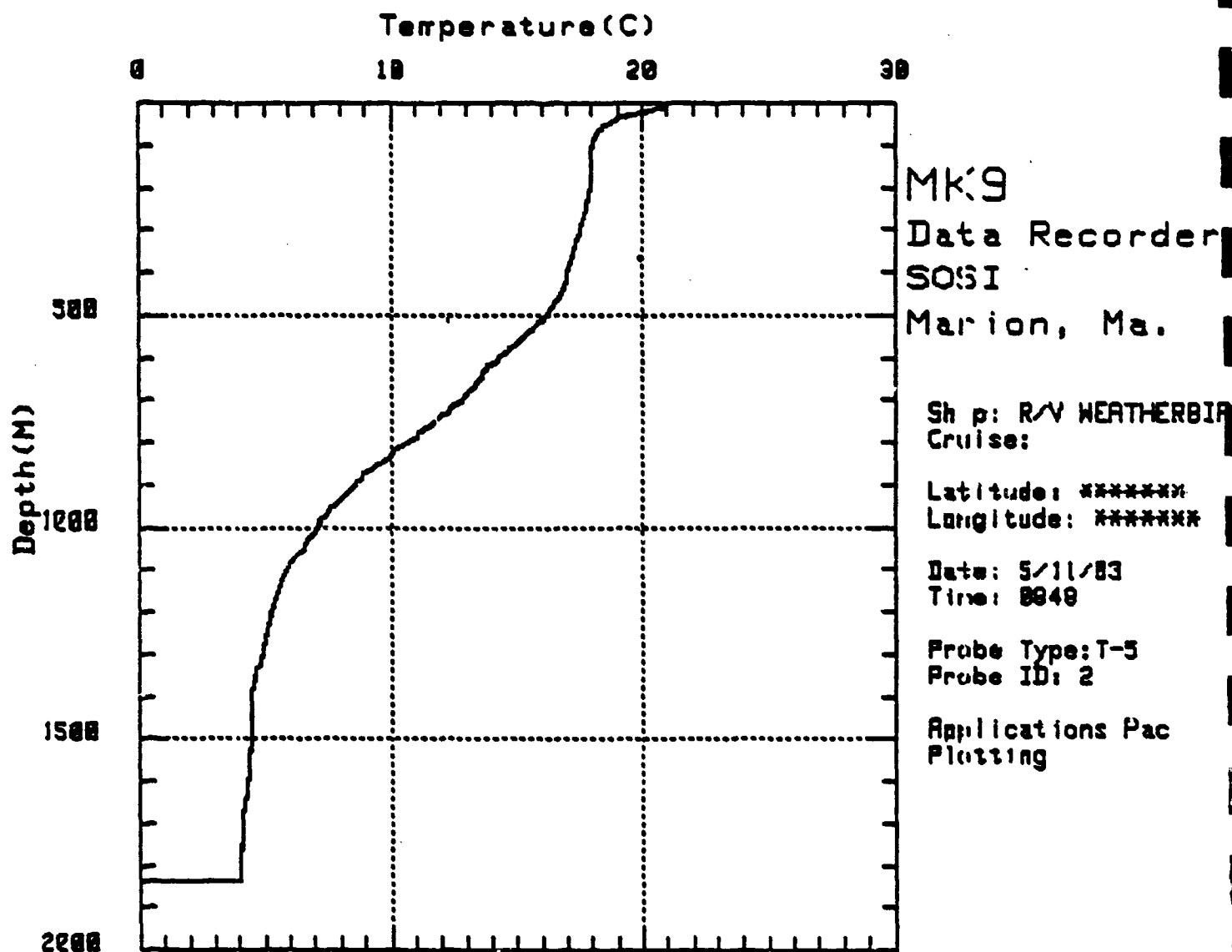


FIGURE 3

TEST STANDARD XBT PROFILE

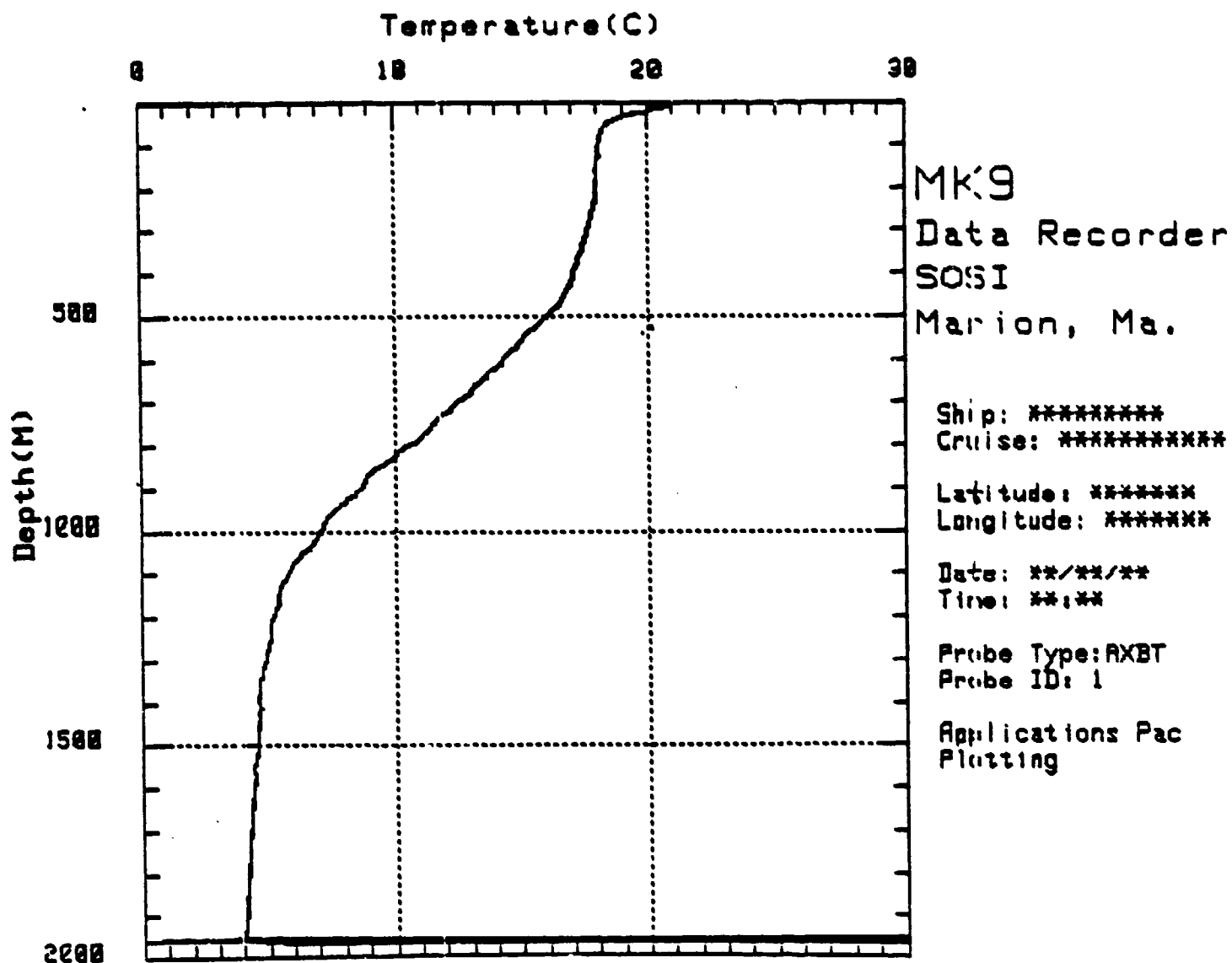


FIGURE 4

2000 METER AXBT PROFILE

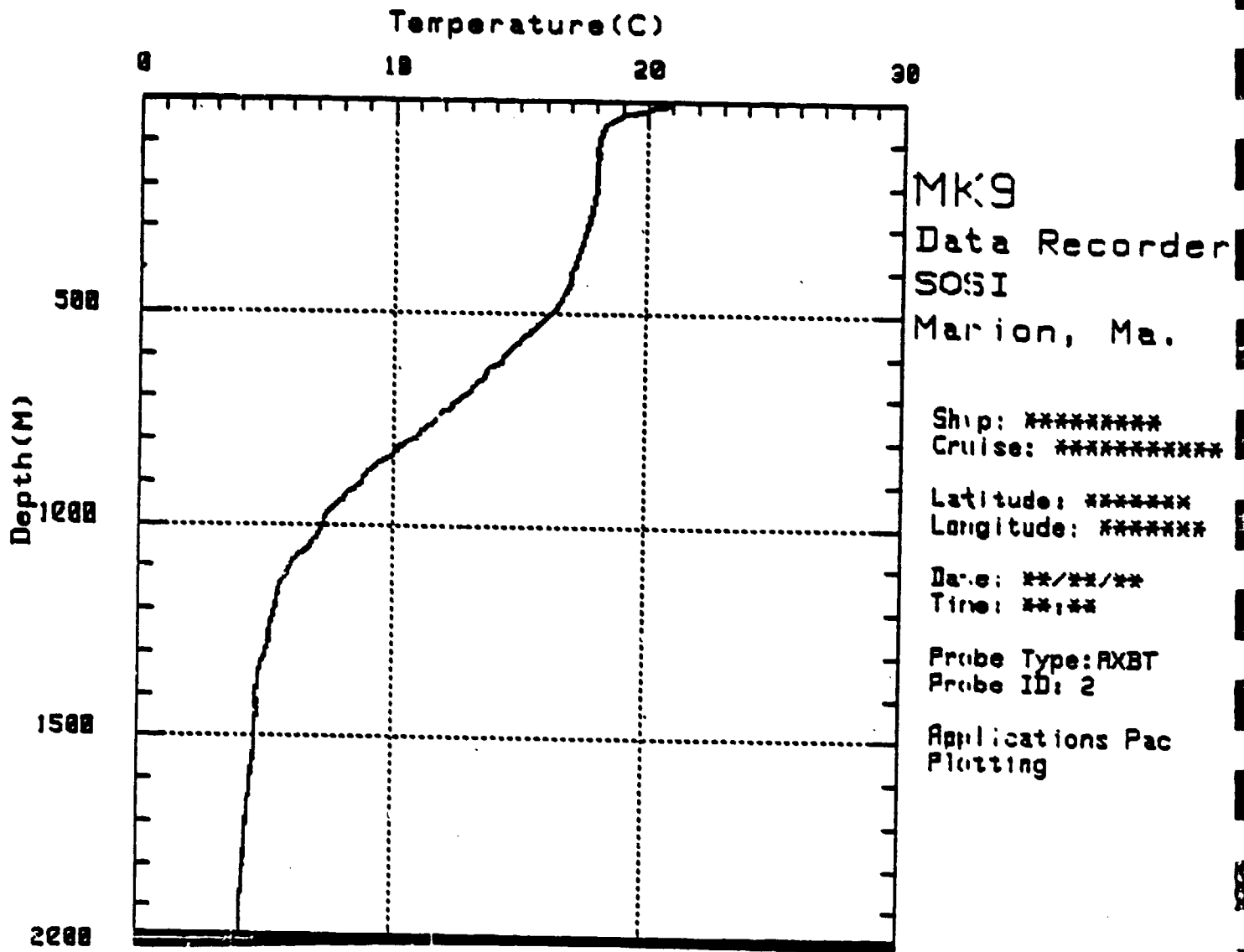


FIGURE 5

2000 METER AXBT PROFILE

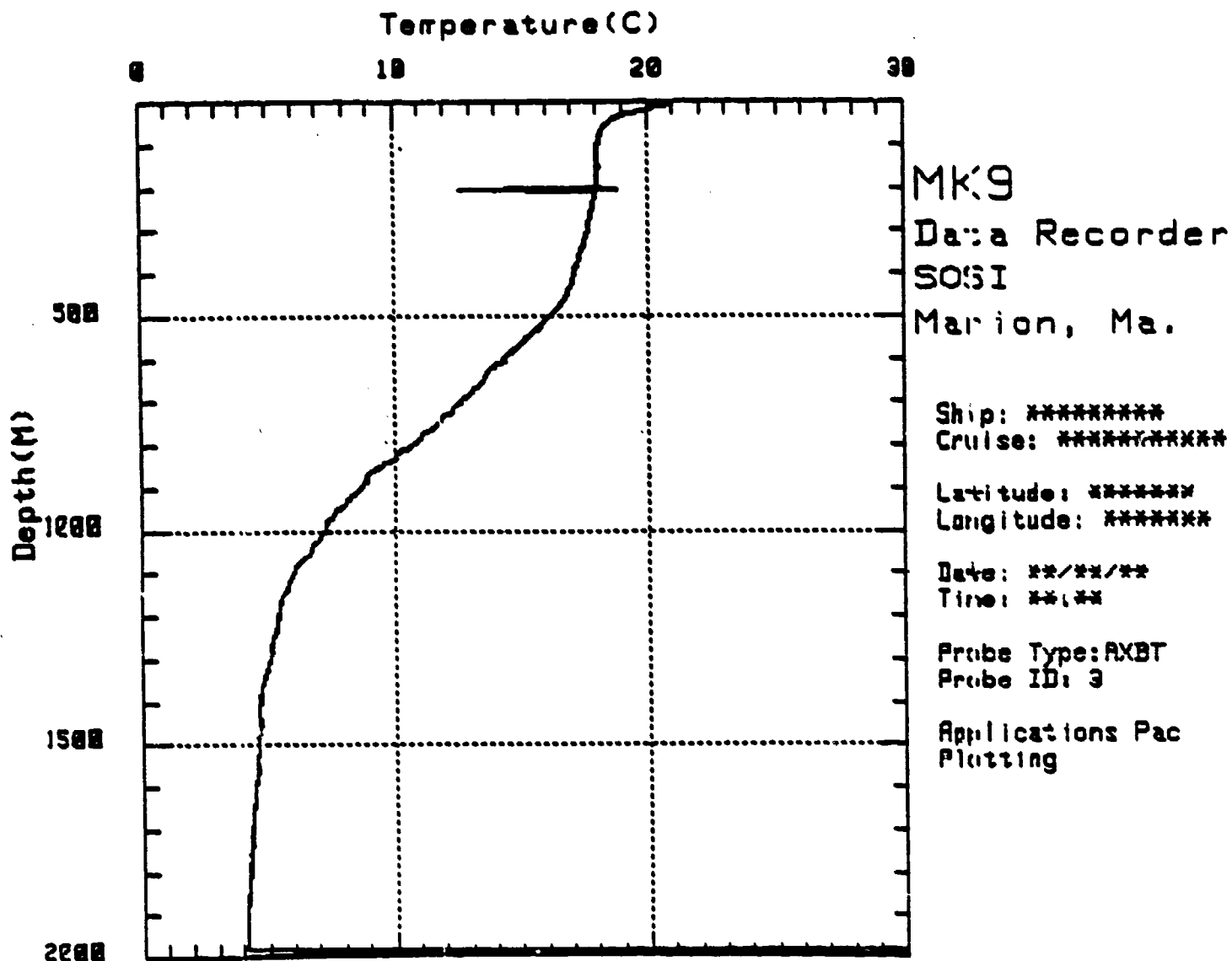


FIGURE 6
2000 METER AXBT PROFILE

TABLE 1. OVER-THE-SIDE TESTING SUMMARY

<u>Drop No.</u>	<u>Time of Drop</u>	<u>Serial No.</u>	<u>Type of Probe</u>	<u>Remarks</u>
1	0934	-	T-5	Noise/Discontinuity
2	0939	11	AXBT	Good Data
3	0950	7	AXBT	Good Data
4	0958	8	AXBT	Good Data
5	1012	3	AXBT	Unusable Data/Off 3 Minutes
6	1017	-	T-5	Good Data
7	1019	9	AXBT	Data 2 Minutes; Cut Off
8	1024	14	AXBT	No Bag Inflation
9	1027	13	AXBT	No Probe Release
10	1031	6	AXBT	No Probe Release
11	1035	-	T-5	Noise/Discontinuity

Comparative plots of the T-5 and each 2000 meter AXBT drop were made (Figures 7-9). These plots show, on an expanded scale, maximum temperature differences of 0.5°C at 700 meters depth. The largest temperature excursions occur in the mid-depth range. These temperature differences may be due to a difference between the actual and estimated drop rate.

PHASE 3 - ENGINEERING AIR DROP

The primary purpose of this test phase was to test the mechanical integrity of the 2000 meter AXBT when deployed from an aircraft. The parts of particular interest were the transmitter, floatation housing, probe release mechanism and the new probe. A second, but also important, objective was to examine the performance of the entire air launch package; parachute deployment, flight stability, release plate and buoy skin separation.

Ten 2000 meter AXBT's were deployed, 13 September 1983, at Naval Avionics Development Center (NADC), Key West, Florida. The AXBT's were launched through a free fall tube at 10 minute intervals. Altitude was approximately 800 feet and aircraft speed was 170 knots.

Data was recorded on a Hewlett-Packard tape recorder. Mechanically, all of the units appeared to remain intact throughout the deployment. On all of the units, air separation from the test aircraft was good and the chute deployments were full and stable. All units floated properly following water impact, all transmitters turned on and all probes released. However, the temperature data collected were not of good quality due to a poor electrical connection to the receiver. This resulted in a failure to record high resolution data due to the presence of high amplitude pulse noise. From real-time examination of the data, during deployment, the data appeared to be of good quality. However, because data were not recorded, this could not be verified.

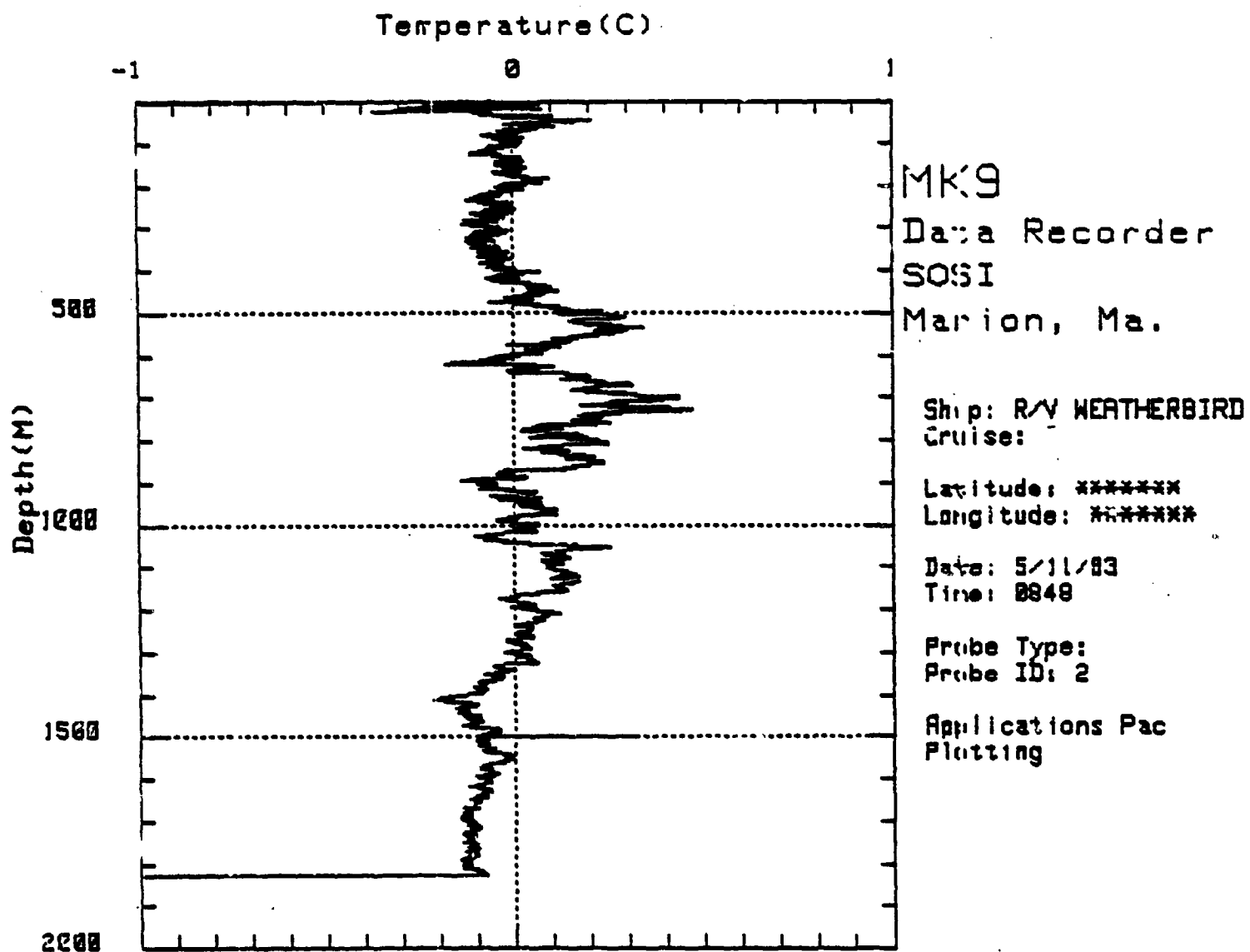


FIGURE 7
COMPARATIVE PLOT
T-5 VS 2000 METER AXBT

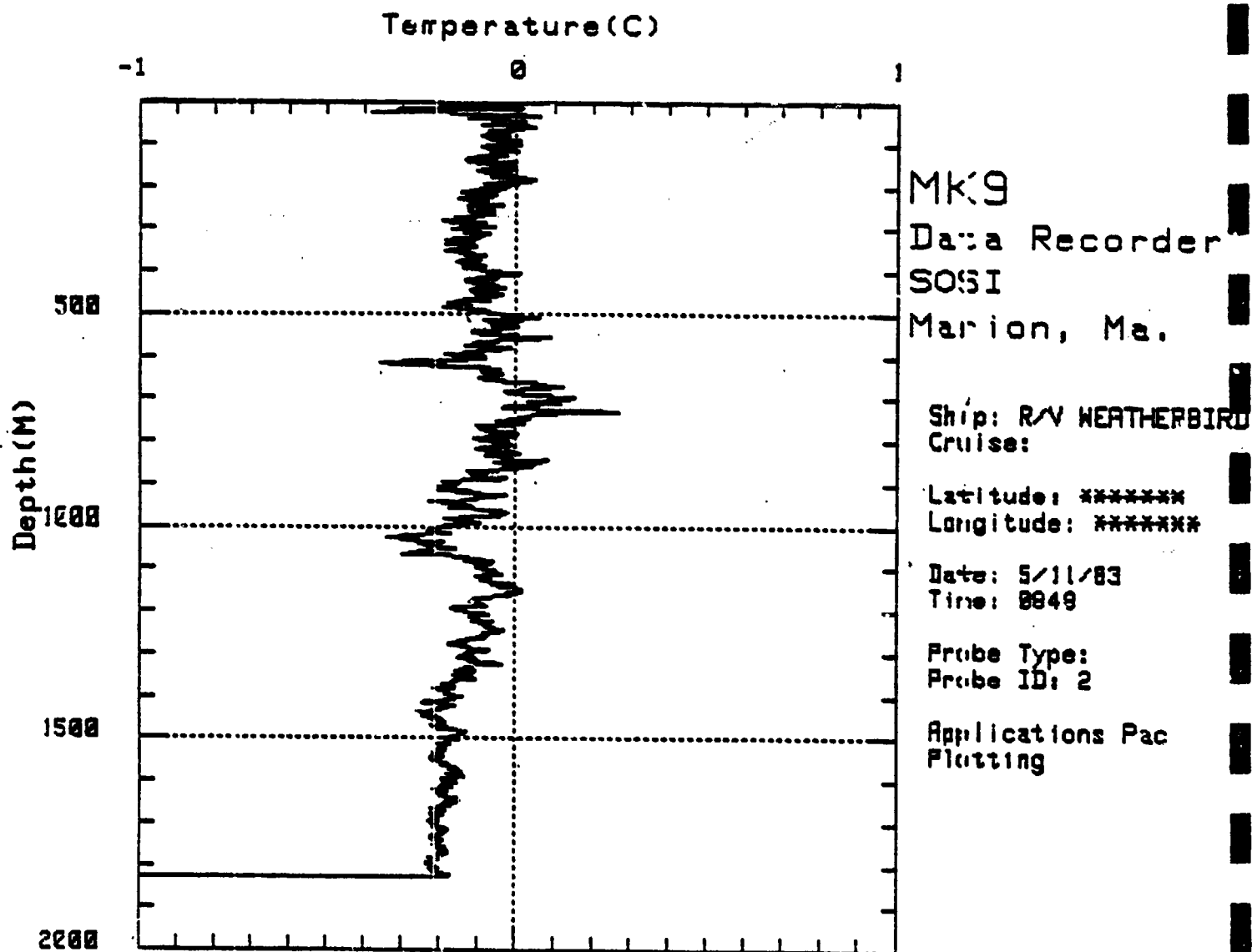


FIGURE 8
COMPARATIVE PLOT
T-5 VS 2000 METER AXBT

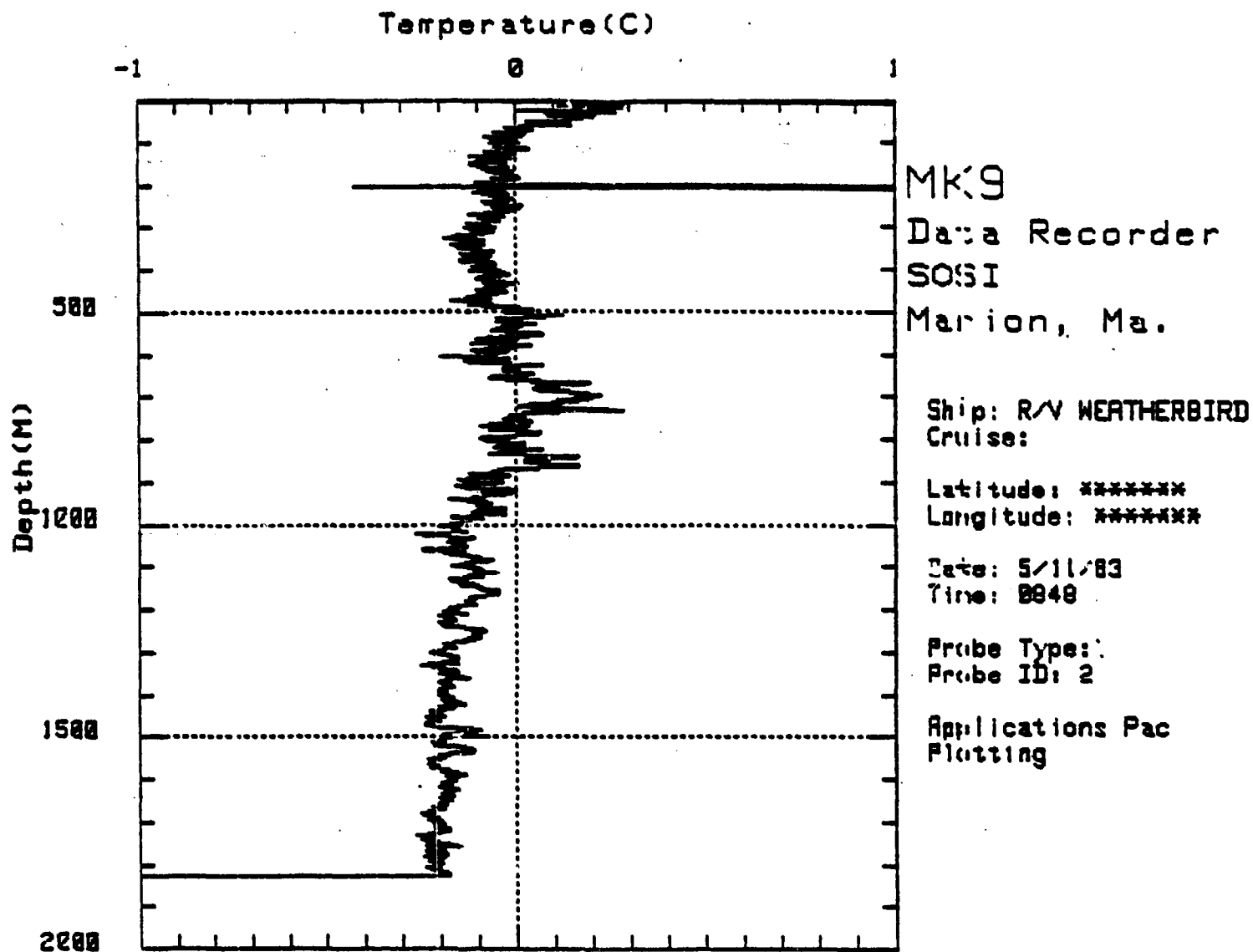


FIGURE 9
COMPARATIVE PLOT
T-5 VS 2000 METER AXBT

PHASE 4 - LABORATORY TESTING

Two 2000 meter AXBT probes were made substituting 1% film resistors for thermistors. These circuits were tested in a pressure chamber as complete circuits and by component. When the circuit was tested under pressure (0-3000 psi), it was found that frequency increased with pressure, corresponding roughly to a 0.15°C temperature increase. Figure 10 is a plot of the temperature offset associated with increased pressure in two 2000 meter AXBT circuits. Pressure testing of individual components was initiated to identify which components were pressure sensitive. At least one component in the circuit (a variable capacitor) was found to drift with pressure.

Laboratory testing was not completed due to budget constraints and are, therefore, inconclusive. Further testing is required before a definite pressure offset relationship can be established and before a solution can be proposed.

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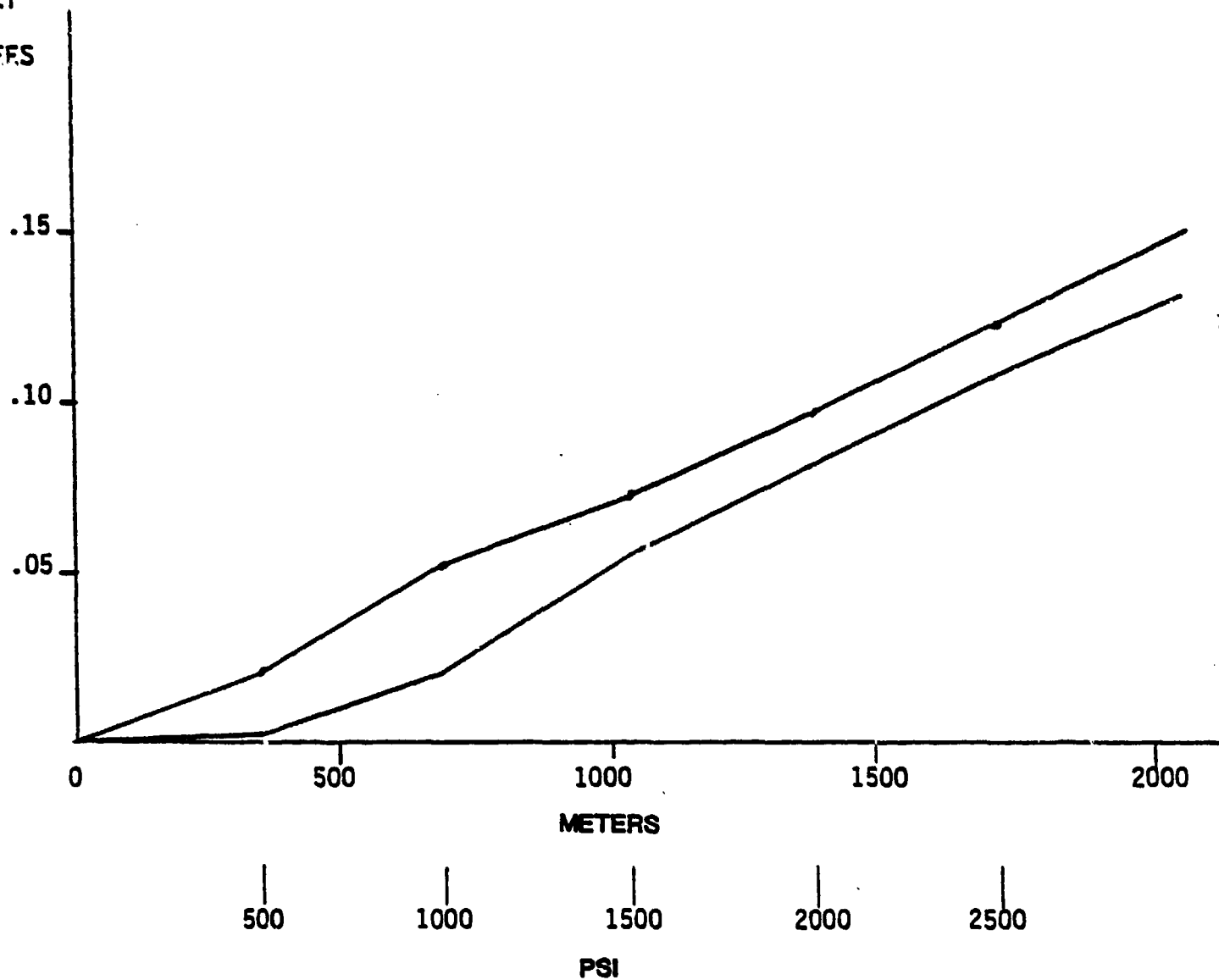


FIGURE 10
TEMPERATURE CHANGE
VS
INCREASING PRESSURE PLOTS
FOR TWO 2000 METER AXBT CIRCUITS

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

from p 1 → The results of the field and laboratory tests suggest that there may be an offset of temperature with increasing pressure. Mechanically, the design appears to be good, however, temperature offsets at high-pressure ranges suggest that the anticipated temperature resolution of 0.1°C was exceeded. The following section outlines the proposed level of effort required to complete the design development of the 2000M AXBT.

Task 1 - Probe Modifications

Modify probe to eliminate temperature offset caused by increasing pressure.

100 hours Engineering

Task 2 - Pressure Test Probe

In-house pressure test for pressure/temperature offset.

80 hours

Task 3 - Probe Drop Rate Testing

Test 5 probes at the NWSC 100 ft. tank to verify the drop rate.

32 hours

Tank rental & expenses \$4,500

Task 4 - Bay Test

Test 2 complete deep AXBT subassemblies for full electrical performance in local waters.

40 hours

Expense \$1,000

Task 5 - Over-the-Side Test

Test 10 full up units at sea to check the temperature/pressure offset and overall electrical performance

80 hours

Expense & Travel \$4,500

Task 6 - Engineering Air Drop

Air launch 10 complete buoys at sea. This is a full mechanical and electrical test.

80 hours

Expense & Travel \$4,500

Task 7 - Performance Evaluation

Analyze the performance of the 20 buoys that were deployed over the side and air launched.

80 hours

Task 8 - Drafting Design Documentation

Documentation for probe redesign.

120 hours

Task 9 - Prototype Buoys

Fab piece parts and assemble 30 complete buoys to support engineering testing.

200 hours
Expenses \$5,000

Task 10 - Final Report

Generate a final report summarizing the design and test results.

40 hours